FCC Special Technologies Work Package

Dr. José Miguel JIMENEZ
Dr. Olivier BRUNNER

FCC Special Technologies
Program for Washington Workshop (1/5)

- Plenary Session (Monday 23/3, 16.00 – 17.00)
  - Special Technologies Overview [J.M. Jimenez (CERN)]

- **Session 1 (Wednesday 25/3, 17.30 – 19.00)**
  Cryogenic Beam Vacuum System Conception [F. Perez, ALBA]
  - Cryogenic beam vacuum specificities applicable to FCC hh
    [V. Baglin (CERN)]
  - Cold test stands for cryogenic beam vacuum qualification
    [A. Krasnov (BINP)]
  - The KEK photon beamline for desorption studies: preliminary results and plans for future studies in the FCC hh context
    [Y. Tanimoto (KEK)]
  - Present and future surface modifications for the mitigation of electron clouds in cryogenic beam vacuum systems
    [R. Valizadeh (STFC)]
  - Potential countermeasures against the very large SR heat load in FCC-hh
    [R. Cimino (LNF-INFN)]

Session 1 (Wednesday 25/3, 17.30 – 19.00)
Cryogenic Beam Vacuum System Conception

- Cryogenic beam vacuum specificities applicable to FCC hh
  [V. Baglin (CERN)]

- Recall:
- Adsorption Isotherms are key ingredients to understand the impact of temperature, gas species and surface properties in a cryogenic vacuum system.

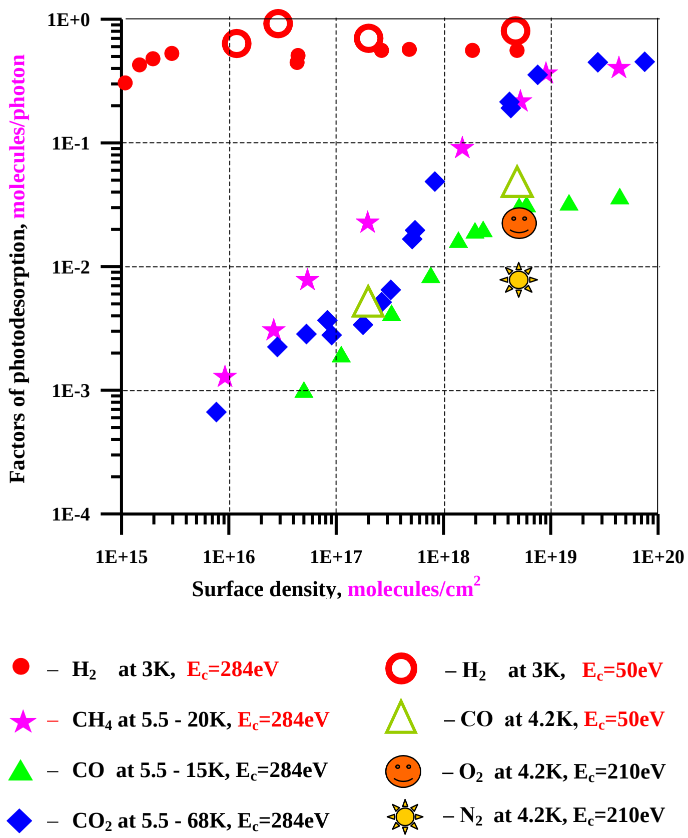
- Perforated beam screens have been proven to be effective during LHC RUN 1 to control the gas density and reduce the beam induced heat load onto the cryogenic system.

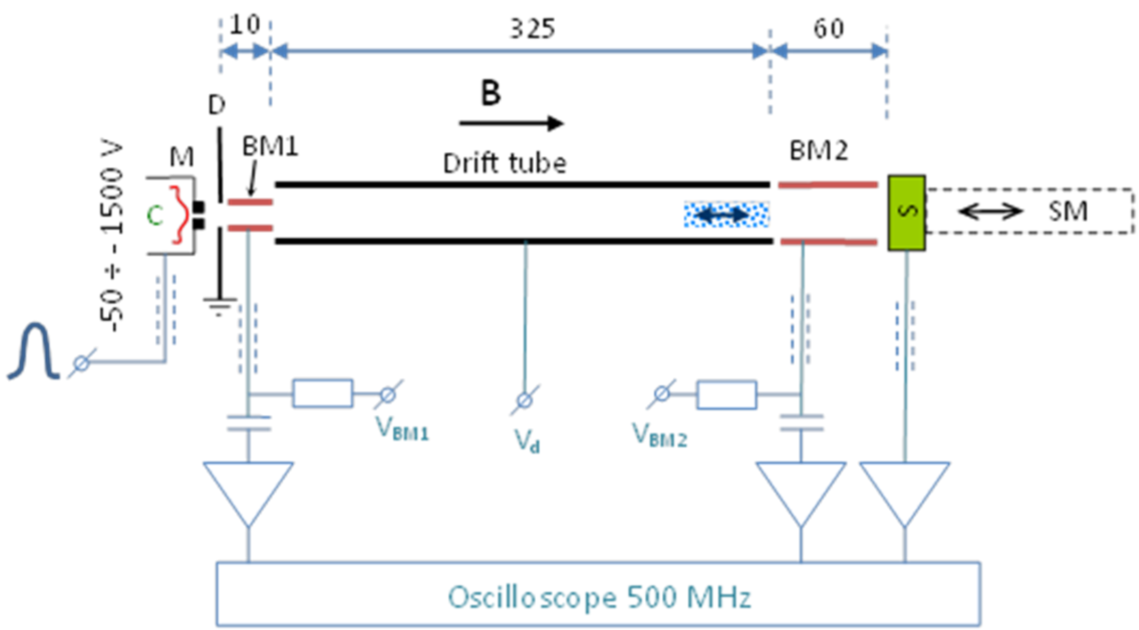
- Input parameters characterising the surface properties and the machine environment of the proposed beam screen material must be studied in details in order to validate and optimise the proposed FCC vacuum system design(s).

Session 1 (Wednesday 25/3, 17.30 – 19.00)
Cryogenic Beam Vacuum System Conception

- Cold test stands for cryogenic beam vacuum qualification
[A. Krasnov (BINP)]

Photo-desorption of condensed gases



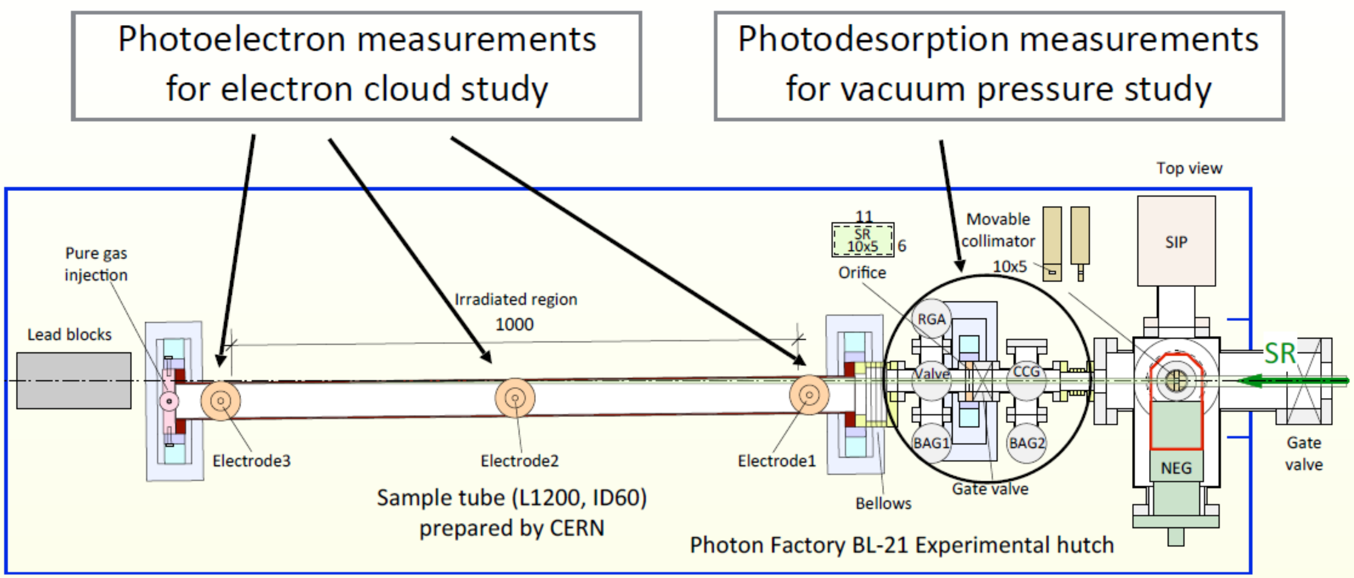


Measuring the SEY in presence of a magnetic field…

Very promising!

Session 1 (Wednesday 25/3, 17.30 – 19.00)
Cryogenic Beam Vacuum System Conception

- The KEK photon beamline for desorption studies: preliminary results and plans for future studies in the FCC hh context
  [Y. Tanimoto (KEK)]



Complementing EuroCirCol studies…

Next Steps:

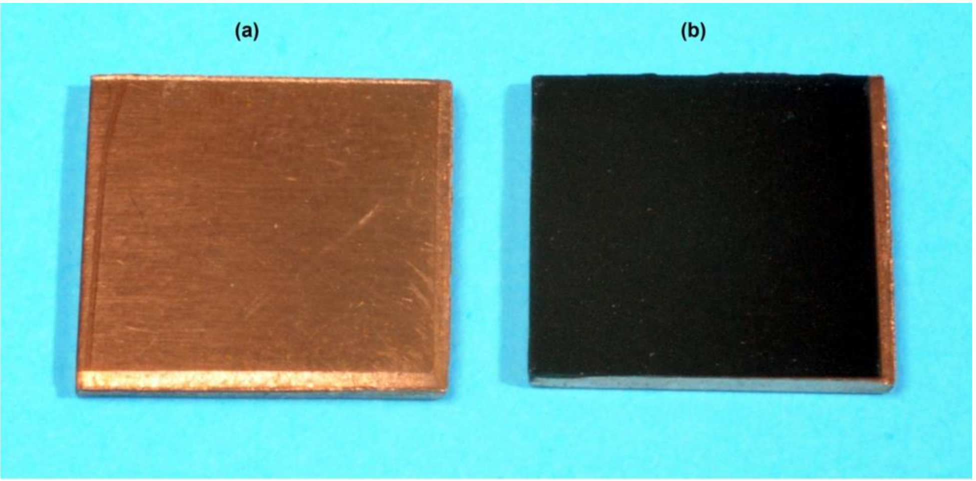
Measurements at 77 K (LN2) to simulate FCC-hh beam screens (40-60 K)

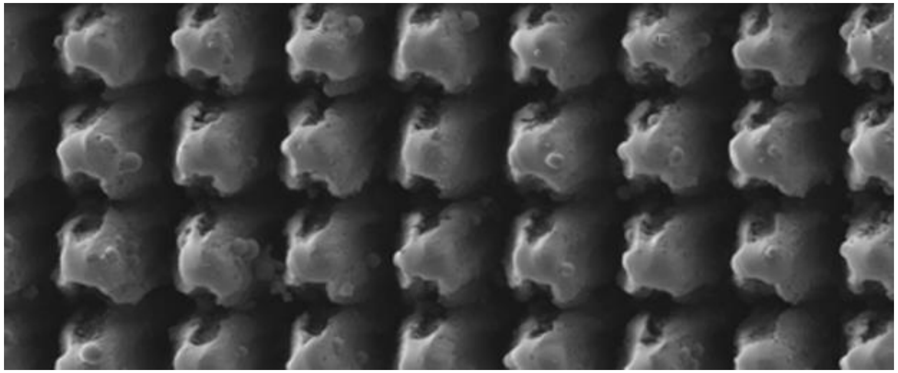
Further studies on NEG surface conditions using the pure gas injection system

Session 1 (Wednesday 25/3, 17.30 – 19.00)
Cryogenic Beam Vacuum System Conception

- Present and future surface modifications for the mitigation of electron clouds in cryogenic beam vacuum systems
  [R. Valizadeh (STFC)]

- The technique can easily be applied to existing vacuum surfaces where the improvement has to be done *in-situ*.
- The blackening process can be carried out in air at atmospheric pressure.
- The process is also readily scalable to large areas.
- The surface is highly reproducible and offers a very stable surface chemistry which can be influenced during the process.





Session 1 (Wednesday 25/3, 17.30 – 19.00)
Cryogenic Beam Vacuum System Conception

- Potential countermeasures against the very large SR heat load in FCC-hh
  [R. Cimino (LNF-INFN)]

- Reflectivity of the Beamscreen (RoB) seems to be an extremely important parameter to be controlled and (eventually) beneficially utilized. In all cases:
  - Validate reflectivity simulations and refine models.
  - Developing and study smooth surfaces and high quality low C coverages (~ 20 nm).
  - Since RoB depends on the first 20 nm… carefully analyze interaction of LT surfaces with residual gas, (physisorbtion), photo-desorbtion (and photochemistry) electron-desorbtion (and induced chemistry)
  - Identify absorbers type and locations.
  - Study and measure realistic Photoelectron Yield and reflectivity, essential ingredients to single bunch and/or e-cloud related instabilities.

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- **Session 2 (Thursday 26/3, 08.30 – 10.00)**
  Technologies R&D [Y. Tanimoto, KEK]

  - Potential reduction of the beam impedance by using HTS coating technology (incl. FCC hh compatibility issues)
    [G. Stupakov (SLAC)]
  - R&D on non-invasive beam profile measurements
    [A. Jeff, Univ. of Liverpool]
  - RadHard Warm Magnet Coils
    [P. Fessia (CERN)]
  - Study of a Magnetic Refrigeration Stage
    [F. Millet, CEA]

Session 2 (Thursday 26/3, 08.30 – 10.00)
Technologies R&D

- Potential reduction of the beam impedance by using HTS coating technology (incl. FCC hh compatibility issues)
  [G. Stupakov (SLAC)]

- At high frequencies, No reduction is predicted by Gennady.

- At low frequencies, considerable improvement in surface conductivity is expected in comparison with Cu.

- A strong thin film and material development and characterization is needed in order to achieve the goals of HTS coatings for a large scale facility such as the FCC-hh.

- Need to develop a surface impedance measurement facility for small-scale HTS films, able to operate in the temperature range 4.2-77 K, up to 16 T external applied magnetic field and at < 1 GHz frequency.

Session 2 (Thursday 26/3, 08.30 – 10.00)
Technologies R&D

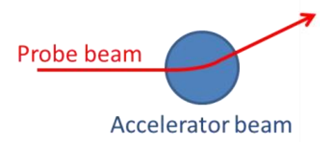
- R&D on non-invasive beam profile measurements
  [A. Jeff, Univ. of Liverpool]

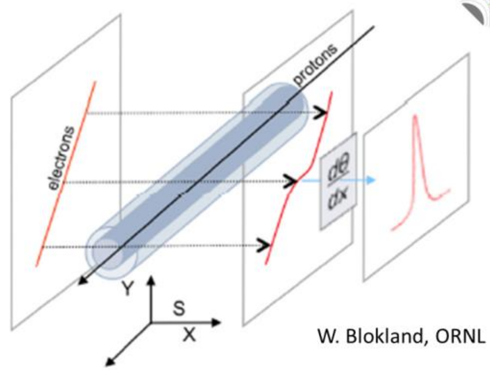
Motivation
- Wire scanners, screens limited to pilot beams due to material damage and losses caused
- Non-intercepting monitors needed for online beam size measurement
- Techniques exist but will be pushed to the limit by small beam size
  - ~100 µm for FCC-hh, vertical size as low as 1.2 µm for FCC-ee

Synchrotron Radiation
- Visible light imaging
- Interferometry
- X-ray imaging

Gas-based techniques
- Ionisation monitor
- Gas fluorescence
- Vertexing
- Gas jet scanner

Crossed Beams
- Laser-wire
- Electron-beam scanner





W. Blokland, ORNL

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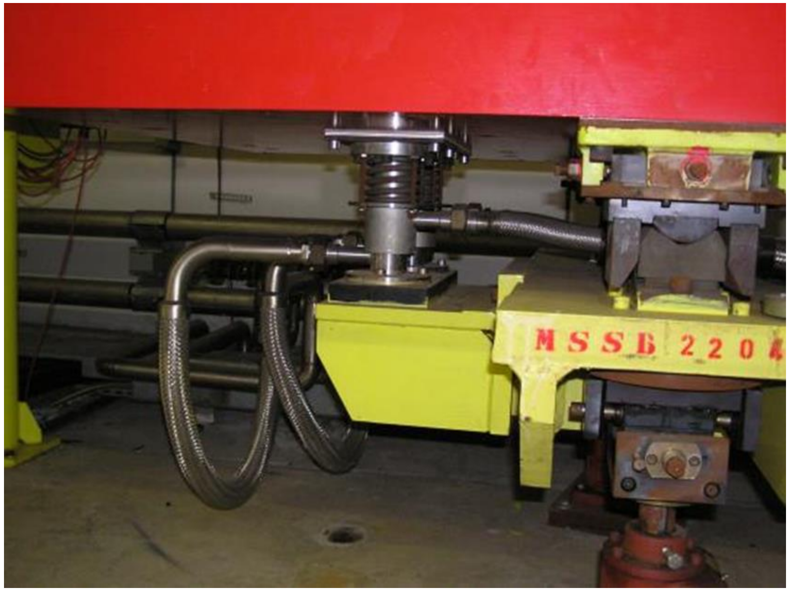
Session 2 (Thursday 26/3, 08.30 – 10.00)
Technologies R&D

- RadHard Warm Magnet Coils
  [P. Fessia (CERN)]

- The development of rad-hard magnets for FCC is a continuum of the LHC Consolidation and HL-LHC.

- A rad hard coils does not mean a rad hard magnet: electrical connection, hydraulic connections and manipulation have to be intimately integrated to provide an homogenous product.

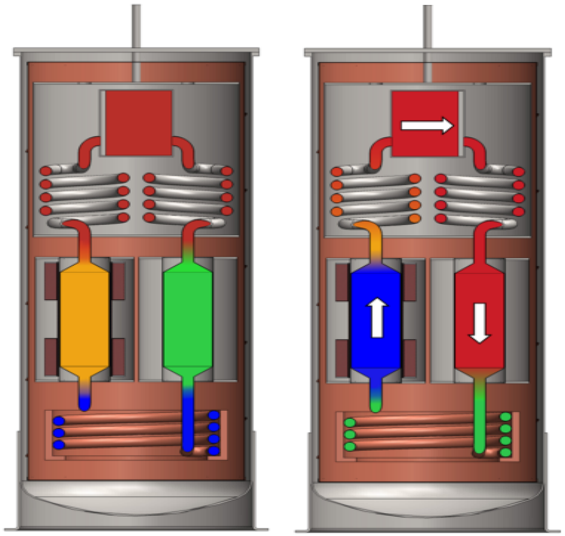


Session 2 (Thursday 26/3, 08.30 – 10.00)
Technologies R&D

- Study of a Magnetic Refrigeration Stage
  [F. Millet, CEA]

Preliminary design

First iteration on design and simulations



Adiabatic Magnetization & Demagnetization

Flow Magnetization & Demagnetization

Cold source	1.6 K
Useful power	*Objectives : up to 5 kW*
FOM	*Objectives : > 50%*
Frequency	*0.1 Hz*
Magnetic field	*4 T*
Magnetic material	*GGG*
Heat transfer	*Oscillating He*
Warm source	***4.2 K***

Work started in the framework of FCC collaboration

Dr. José Miguel JIMENEZ (Coordinator)
CERN, Technology Department

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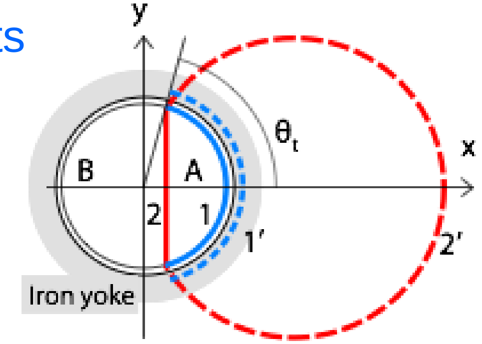
Program for Washington Workshop (3/5)

- **Session 3 (Thursday 26/3, 10.30 – 12.00)**
  Beam Transfer & Instrumentation [E. Fischer, GSI]

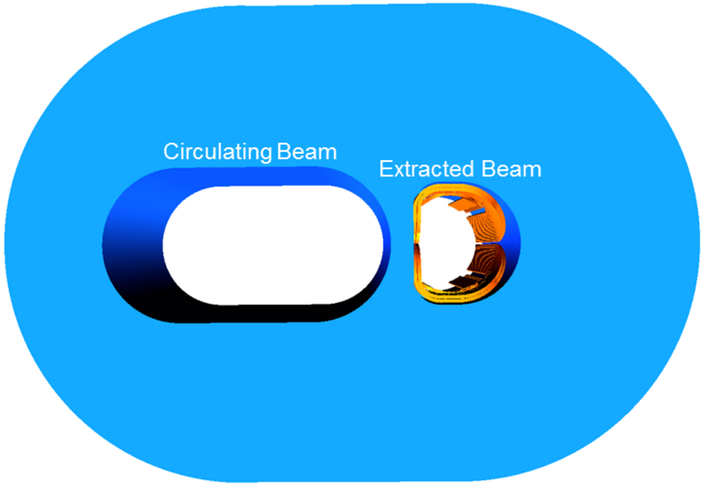
  - Superconducting Septa and Fast Ramped Cos Theta Magnets
    [E. Fischer (GSI)]
  - Further R&D on beam instrumentation for HE proton colliders
    [H. Schmickler (CERN)]
  - Semiconductor Switch designs
    [M. Barnes (CERN)]
  - Beam Dump concepts & Design
    [W. Bartmann (CERN)]

Session 3 (Thursday 26/3, 10.30 – 12.00)
Beam Transfer & Instrumentation

- Superconducting Septa and Fast Ramped Cos Theta Magnets [E. Fischer (GSI)]



- Main Design Aspects
  - Field quality: trade-off
    - Ideally the iron yoke radius should be as close as possible to the cosine-theta current radius.
    - By introducing the non-magnetic collar to avoid effect of iron saturation, field quality may be degraded.
  - Cable design: Keystoned cable, flat cable or Nuclotron cable
  - Coil end design
  - Magnetic force: maintained by the septum wall



Session 3 (Thursday 26/3, 10.30 – 12.00)
Beam Transfer & Instrumentation

- Further R&D on beam instrumentation for HE proton colliders [H. Schmickler (CERN)]

Why will the FCC instrumentation be a success?

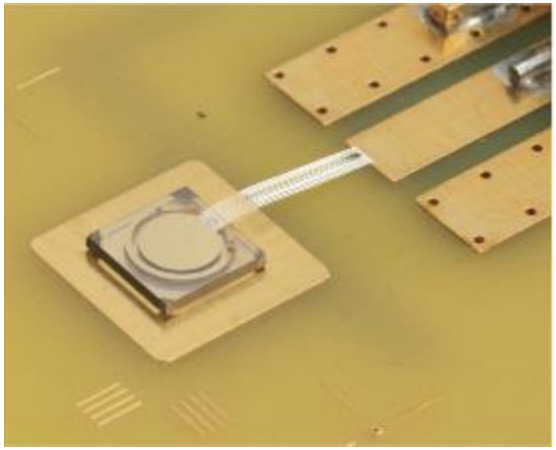
1) "Never make an economy on beam instrumentation",
very important quote still to come from M.Benedikt et al.…

2) Direct experience from LHC; relevant for all instruments.

3) Early, well documented specifications
BE-BI will start this year with a small WG under guidance of J.J.Gras

4) New collaborations to enlarge R&D in the following domains:
- Beam parameter feedbacks
- Non invasive profile measurements
- Electro-optical devices for longitudinal diagnostics& instability monitoring
- Radiation tolerant electronics & communication platforms

26.3.2015 FCC Meeting Washington March 2015, HS 35



Cryogenic BLMs

Diamond BLM detector, courtesy of E. Griesmayer

Session 3 (Thursday 26/3, 10.30 – 12.00)
Beam Transfer & Instrumentation

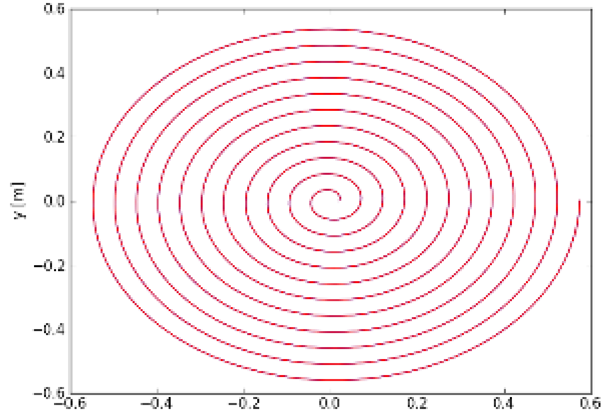
- Semiconductor Switch designs
  [M. Barnes (CERN)]

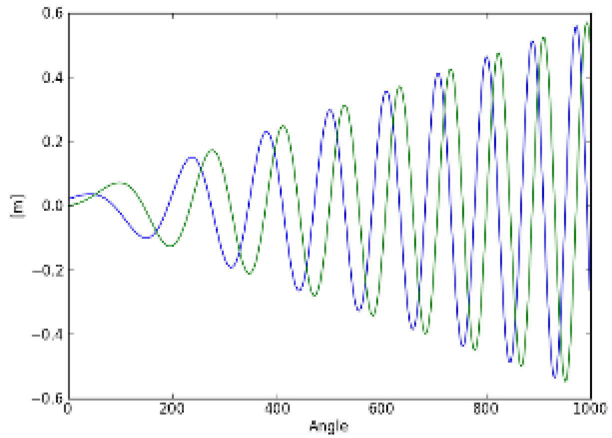
- Very **challenging** requirements;
- **High reliability** kicker systems are required for FCC;
- Parallel and series arrays of semiconductor switches are promising for both FCC and consolidation of existing kicker systems;
  - **eliminate pre-fire** associated with thyratrons;
  - eliminate need for very high voltage rating **coaxial cable**;
  - built in **redundancy**;
  - **modularity**.
- Closing and opening capability eliminates the need for a **PFL/PFN**;
  - Source impedance can be low, allowing a relatively small number of series connected power semiconductors. BUT requires a careful consideration of fault conditions;
- **Redundancy, fault tolerance, radiation tolerance**,…

Session 3 (Thursday 26/3, 10.30 – 12.00)
Beam Transfer & Instrumentation

- Beam Dump concepts & Design
  [W. Bartmann (CERN)]

- Three concepts being studied
  - LHC scaled, SSC like and Asymmetric
  - Overall dump insertion length ~1200 m per beam
  - Further protection elements outside the insertion likely needed – link to collimation system
- Experience with LHC dump system
  - Manage 200 MJ
- In FCC we have to manage 8.5 GJ – explore scaling LHC
  - Avoid asynchronous dump at all by segmenting the kicker system
  - Dump made of gas, liquids,…





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Program for Washington Workshop (4/5)

- **Session 4 (Thursday 26/3, 13.30 – 15.00)**
  Beam Dump & Collimators: Materials & Engineering breakthroughs
  [O. Brunner, CERN]

  - Evolution and Limits of the Present Collimation Materials Studies
    [A. Bertarelli (CERN)]
  - Energy Deposition Challenges: Best Materials for Collimators?
    [A. Lechner (CERN)]
  - State-of-the-Art and Future of Additive Manufacturing
    [D. France (3T RPDT)]

Session 4 (Thursday 26/3, 13.30 – 15.00)

Beam Dump & Collimators: Materials & Engineering breakthroughs

- Evolution and Limits of the Present Collimation Materials Studies [A. Bertarelli (CERN)]

(2012) HiRadMat Impact Test on specimens of 6 different material (High-Z to low-Z)

Tungsten Alloy, 0.65 MJ

Molybdenum, 0.65 MJ & 1.3 MJ

Glidcop, 0.65 MJ

Copper-Diamond, 1.3 MJ

Mo-Cu-Diamond, 1.3 MJ

Mo-Graphite (3 grades), 1.3 MJ

Session 4 (Thursday 26/3, 13.30 – 15.00)
Beam Dump & Collimators: Materials & Engineering breakthroughs

- Energy Deposition Challenges: Best Materials for Collimators? [A. Lechner (CERN)]
- How much power deposition do we expect in primary collimators for short beam lifetimes?
  - For beam lifetimes of 0.2 h, the power deposition in a single jaw can exceed 100kW
- Can we safely intercept a single 50TeV bunch with absorber materials presently used in the LHC?
  - Yes, if the beam spot size is at least a few hundred m (in both planes)
  - For smaller sizes, the peak temperature induced by a single bunch in Graphite or CfC can easily exceed 1000C and stresses can be beyond material limits
- Can the materials of the present LHC dump cope with 50 TeV beams?
  - At a first glance, yes, if the sweep path length is at least 20m
- Conclusion:
  - FCC beams are certainly challenging even for the most robust materials presently used in the LHC
  - Evidently, the main issue are accidental beam losses

Session 4 (Thursday 26/3, 13.30 – 15.00)

Beam Dump & Collimators: Materials & Engineering breakthroughs

- State-of-the-Art and Future of Additive Manufacturing
  [D. France (3T RPDT)]

Confidence in the technology is growing fast!

With this we will see the development of new materials and machines…

FCC Special Technologies
Program for Washington Workshop (5/5)

- **Session 5 (Thursday 26/3, 15.30 – 17.00)**
  Magnets (Resistive) & Machine Protection [M. Capeans, CERN]

  - Architecture of powering and protection systems for high field circuits
    [R. Schmidt (replacing A. Siemko) (CERN)]
  - Concept & Architecture of the machine protection systems
    [R. Schmidt (CERN)]
  - Beam induced damage and hydrodynamic tunnelling
    [N. TAHIR (GSI)]
  - R2E technology challenges for the future
    [R. Baumann (Texas Instruments (TI))]

Session 5 (Thursday 26/3, 15.30 – 17.00)
Magnets (Resistive) & Machine Protection

- Architecture of powering and protection systems for high field circuits
  [A. Siemko (CERN)]

- Magnets with a field of 16 T magnet are very challenging
- The FCC powering and protection system to safely power a string with such magnets is similarly challenging
- Simple scaling from LHC will result in a system that is too expensive, and cannot be efficiently operated
- Shorter powering sectors are preferred
- For the system to ensure safe and efficient powering of the magnets, new ideas and R&D on new technologies is required!

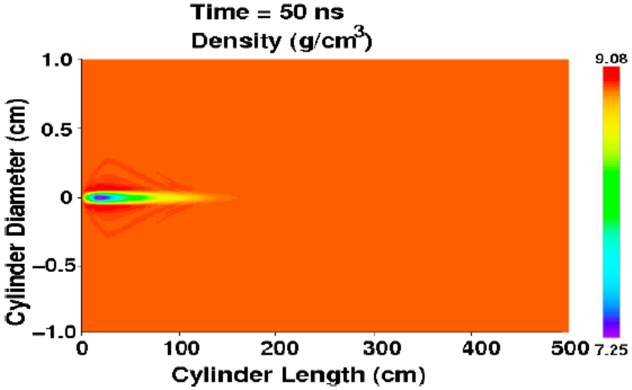
Session 5 (Thursday 26/3, 15.30 – 17.00)
Magnets (Resistive) & Machine Protection

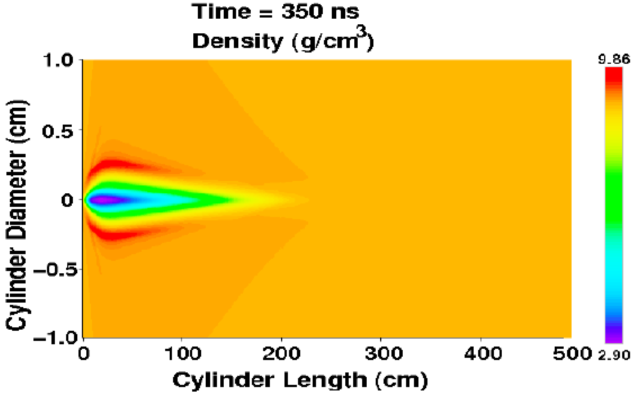
- Concept & Architecture of the machine protection systems
  [R. Schmidt (CERN)]

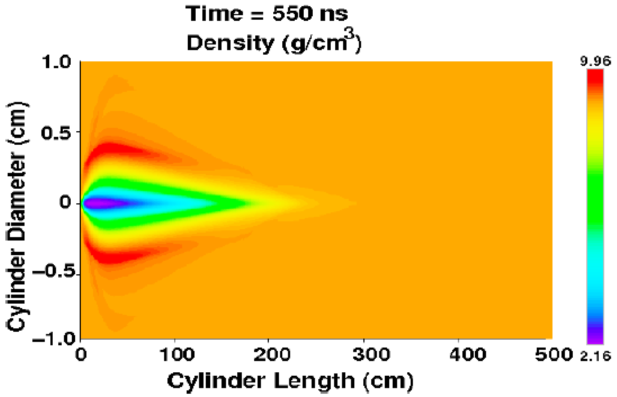
- FCC will profit from LHC experience in machine protection
- **Machine Protection ≠ Interlock System**
- Machine Protection: **Methods and technologies to identify, mitigate, monitor, and manage the technical risks associated with the operation of accelerators with high power beams** or sub-systems with large stored energy, **if failure modes can result in substantial damage to accelerator systems or significance interruption of operations.**
- Machine Protection includes an ensemble of hardware systems + software + commissioning and operational procedures + ….
- Successful implementation of machine protection **requires a safety culture at the lab**

Session 5 (Thursday 26/3, 15.30 – 17.00)
Magnets (Resistive) & Machine Protection

- Beam induced damage and hydrodynamic tunnelling
  [N. TAHIR (GSI)]







Session 5 (Thursday 26/3, 15.30 – 17.00)
Magnets (Resistive) & Machine Protection

- R2E technology challenges for the future
  [R. Baumann (Texas Instruments (TI))]

- Technology Scaling has reduced rad sensitivity BUT a wide number of rad environments cannot be serviced by COTS alone.

- Making the correct choices is HARD & mistakes are expensive!

- Invest in radiation characterization and modeling (Tools) & build and maintain radiation expertise and experience (People).

- COTS+, MIL, EP, Space parts can help meet many system reqs. BUT component solutions are not sufficient at higher fluences.

- Disparate R&D group requests should be organized and combined when possible = better pricing through volume!

Special Technologies

Factor of Merit

- 20 talks,
- 20 different domains
- 20 minutes durations

- and we'll get ready for the CDR in spring 2018 !

- Welcome on Board.

Acknowledgements

- Many thanks to all Speakers and Contributors who helped us to build very dense and intensive sessions, opening the way to many interesting topics and challenges for the coming years.

- Thanks to the Sessions’ Chairs for the perfect management of discussions and time.

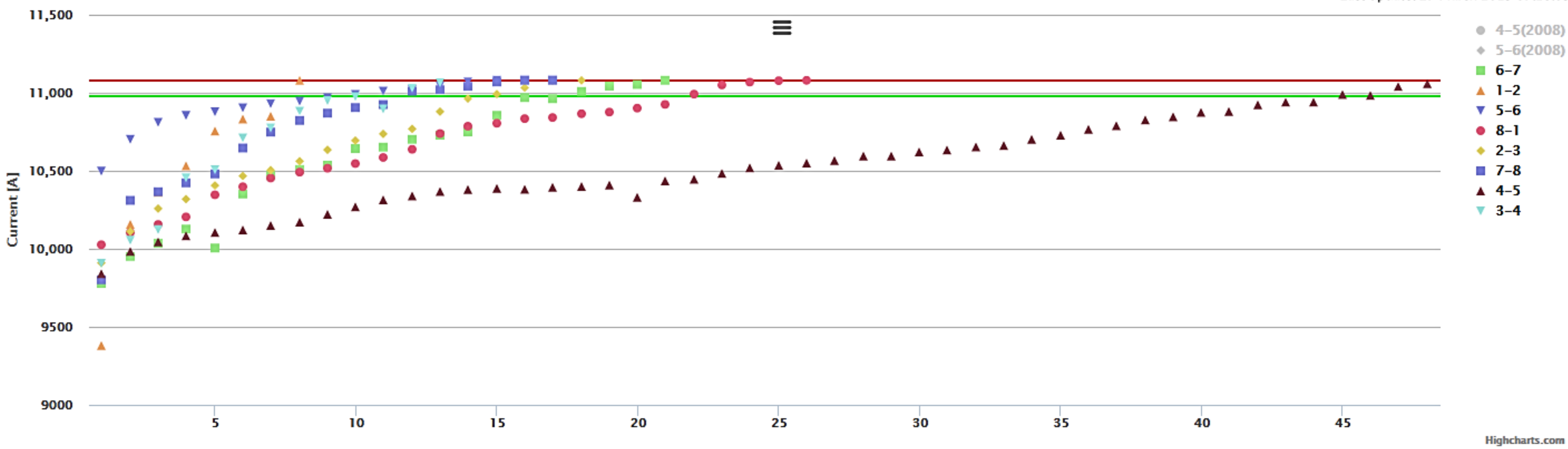
- Thanks to O. Brunner (CERN) and Colleagues of the Program Committee for their help in preparing these sessions.

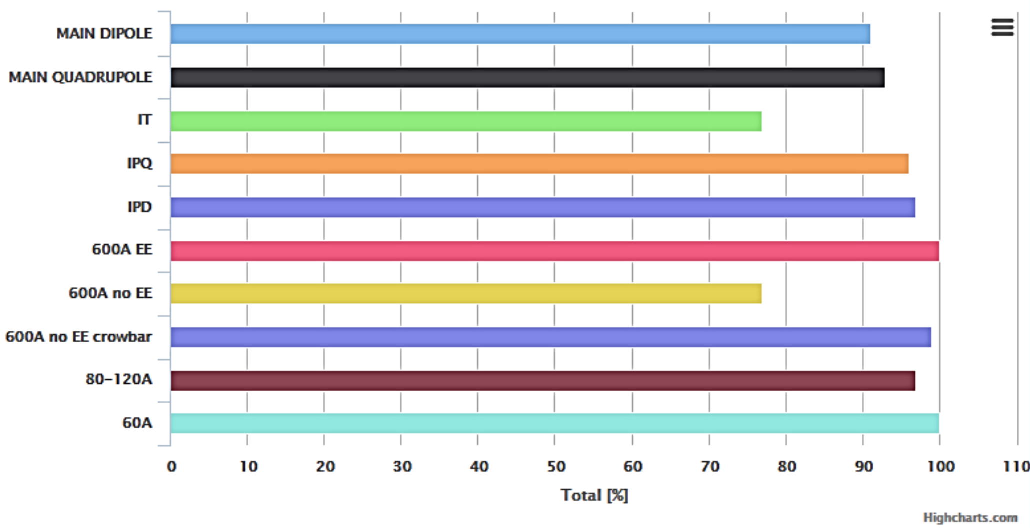
CERN

Post-LS1 Powering Tests Campaign

The campaign of re-commissioning of the superconducting circuits after LS1 started on September 10 and will continue till early 2015.
You can find below the cumulative number of powering steps executed on the available circuits.

Last update: 27 March 2015 07:18:03





Latest Quenches

Sector	MAX I [A]	MAX E [TeV]	Date	N of Quenches
1-2	11080	6.55	19-01-2015	7
2-3	11080	6.55	28-02-2015	17
3-4	11064	6.55	21-03-2015	13
4-5	11059	6.55	27-03-2015	48
5-6	11080	6.55	08-02-2015	16
6-7	11080	6.55	10-12-2014	20
7-8	11080	6.55	12-03-2015	16
8-1	11080	6.55	22-02-2015	25

The target for 2015 is 10980 A <=> 6.5 TeV, with 100 A of margin for stable operation. Once the circuit has reached 11080 A, the training quench campaign is closed in the concerned sector.